DRAFT- DOH Review: Navy Groundwater Flow Models & Related Issues with the Navy CSM for the Red Hill Facility

By:

The Department of Health Hawaii (DOH)
Technical subject matter experts
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In coordination with EPA, Region 9

October 19, 2021

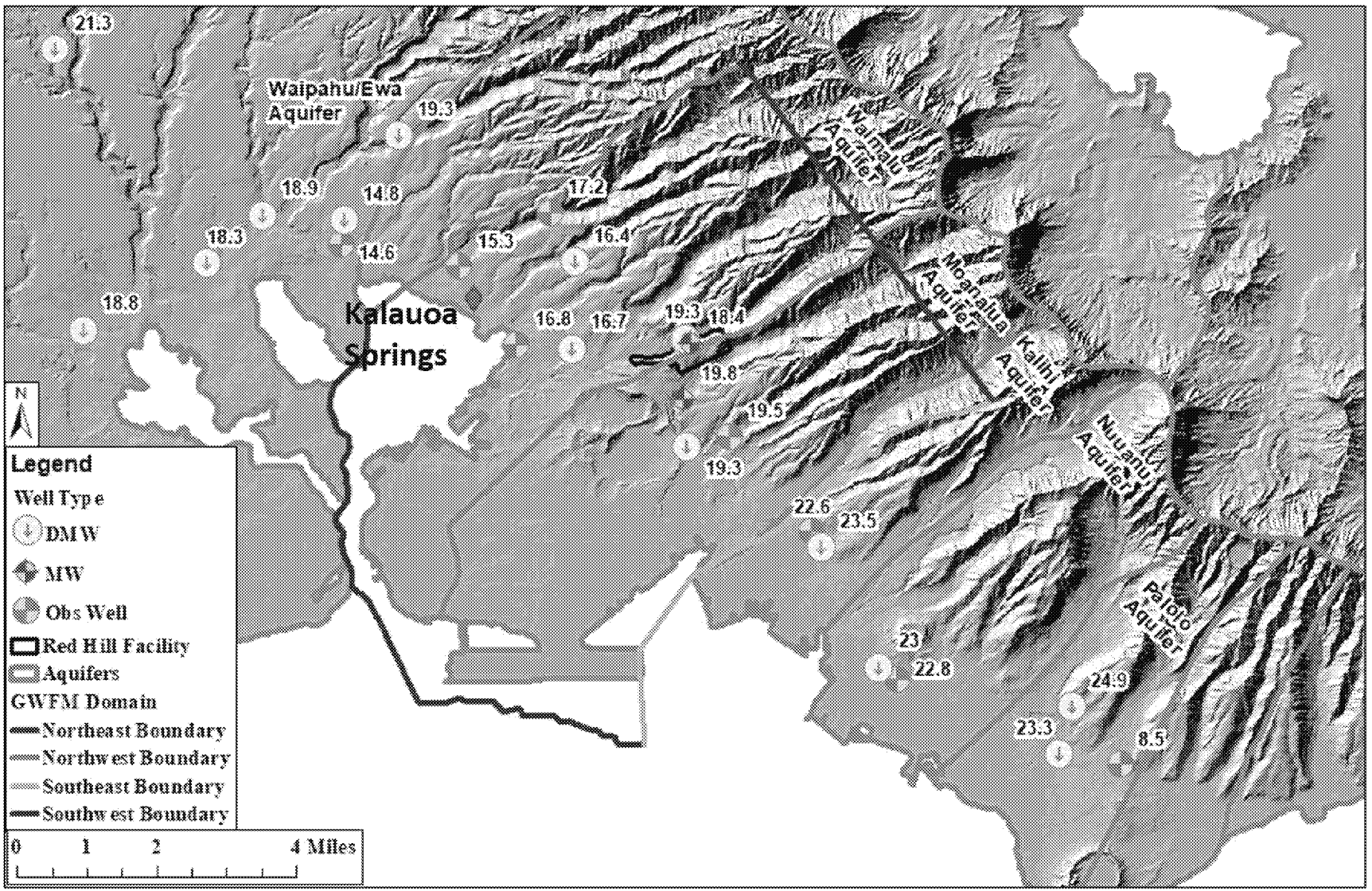
GWFM - Drinking Water Risk Concerns

1. GWFMs boundary condition uncertainty
   a) Chosen BCs are reasonable for primary models
   b) However, new data leads to the uncertainty
2. Currently used head data don't ensure the model replicates hydrogeologic dynamics with certainty
   a) Currently used comparative data – g.w. gauging
   b) Alternative verification data sets
3. Model conclusions and data contrasts are problematic
   a) Critical question: Do the model results support the conclusions in the IRR Report?
   b) And future CF&T (Part II discussion)

Critical Drinking Water Risk Evaluation Questions

- Does pumping the Red Hill Shaft mobilize groundwater from beneath the tanks toward the Red Hill Shaft?
- Is there an unobstructed hydraulic pathway from beneath the tanks to the Halawa Shaft?
- Over-arching question:
  - Is the model informative for answering either or both of those questions?
  - Can the models adequately inform CF&T (Part II)?

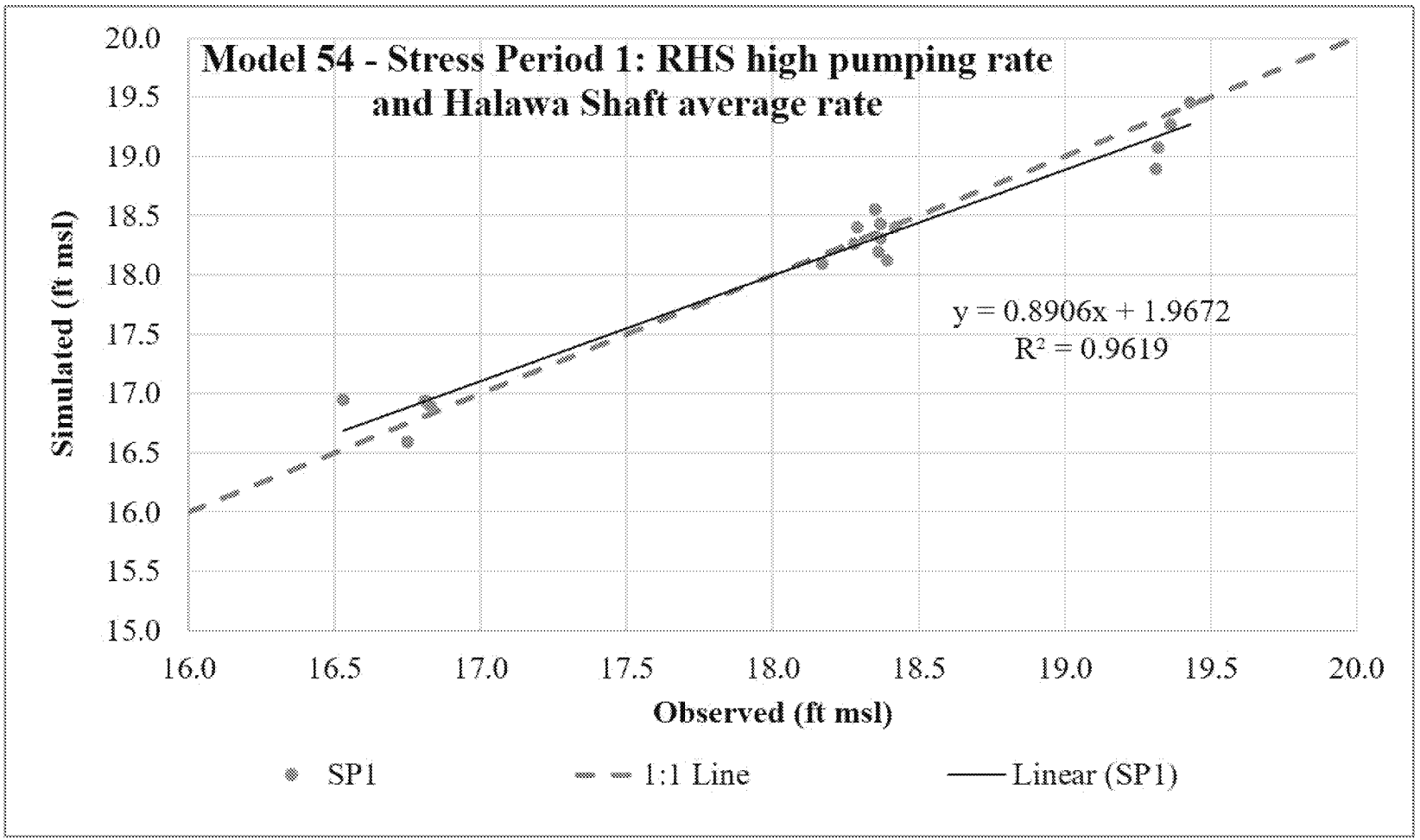
GWFM Boundary Conditions



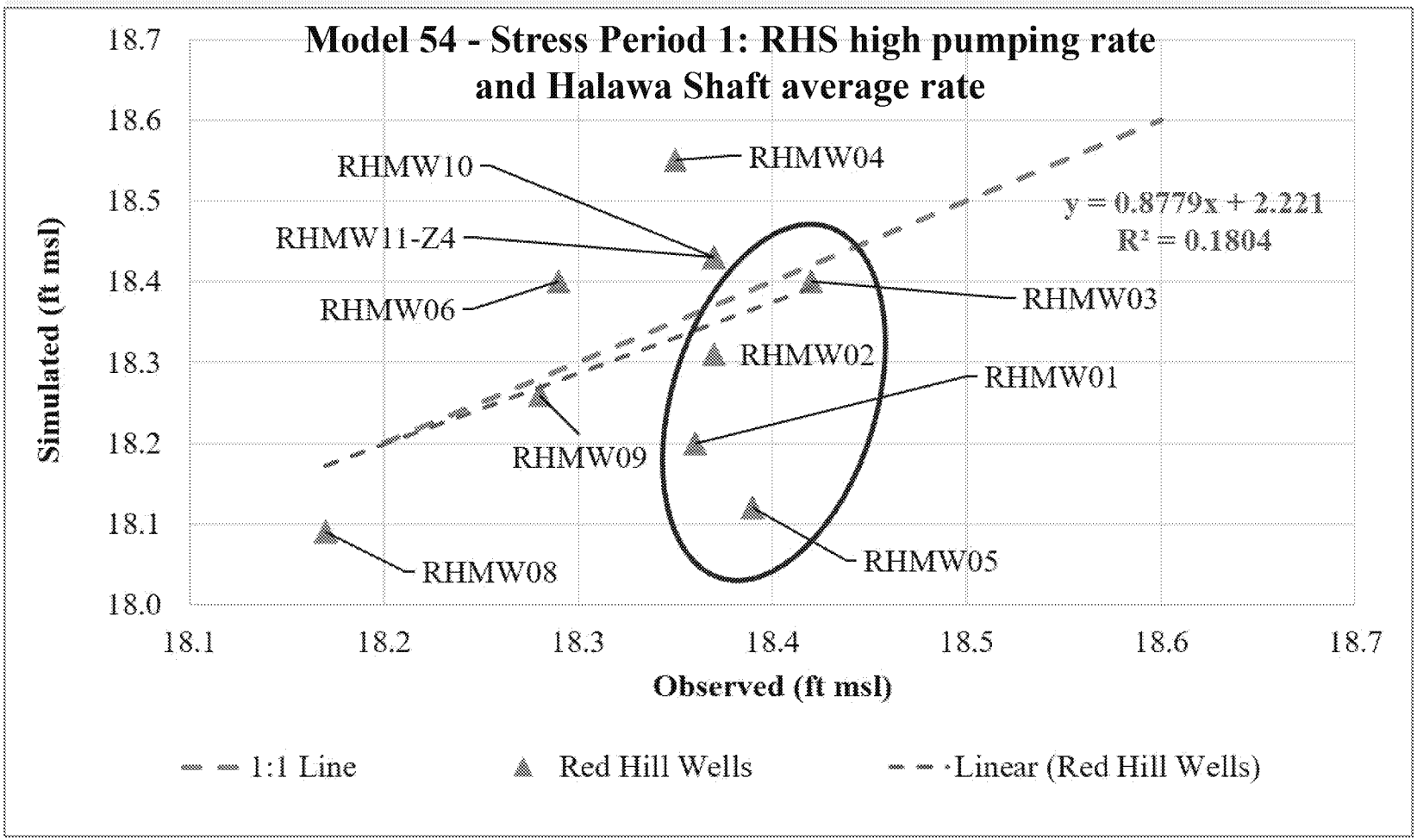
Model Validation – Compare to Site Data

1. Metrics currently used
   a) Groundwater elevations
   b) Transient responses
   c) Others
2. Concern with current comparative data
   a) Mis-match between modeled and measured gradients
   b) Groundwater elevations have low accuracy
3. Alternative groundwater behavior data
   a) Chloride and other natural tracers

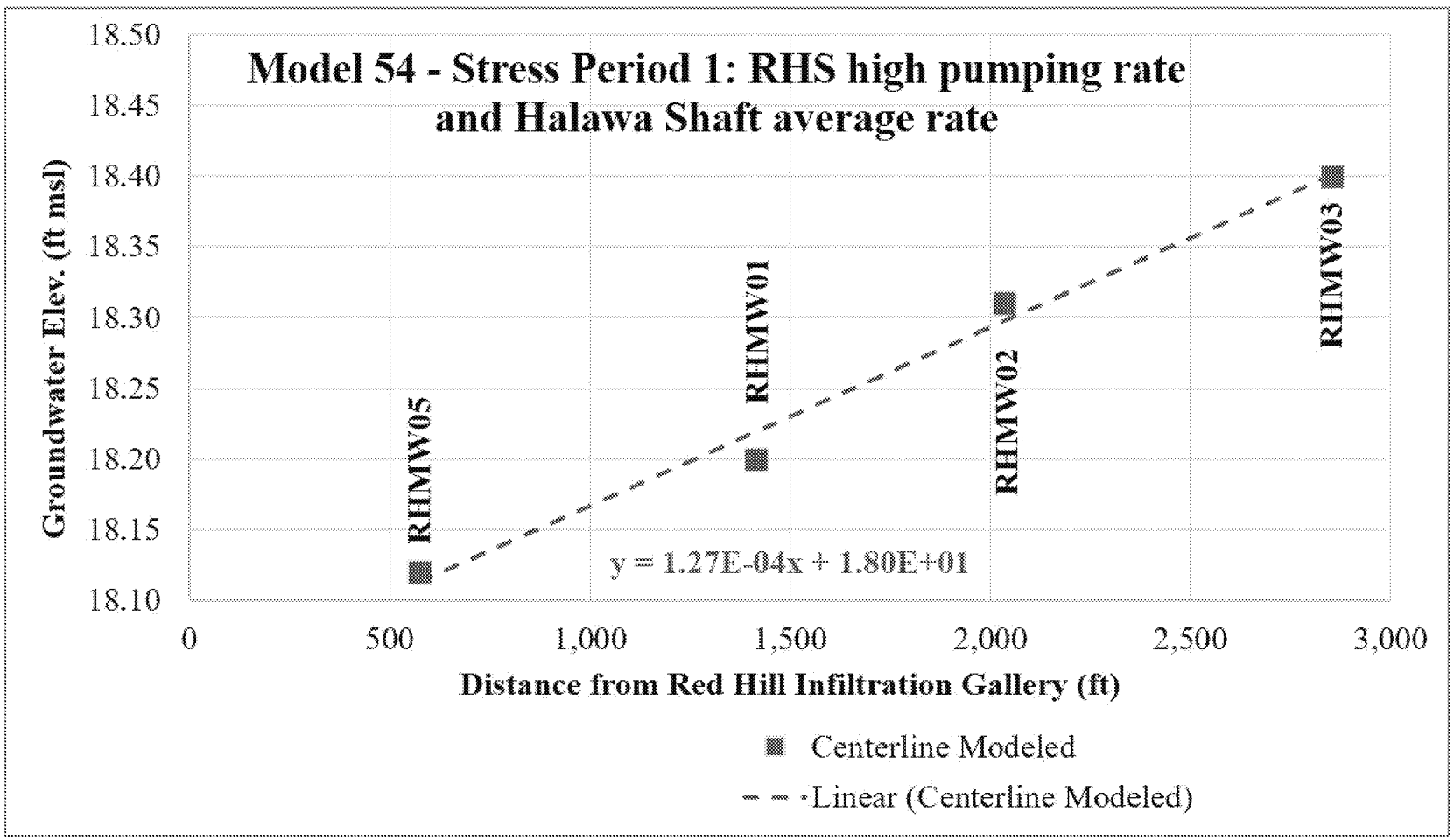
Regional Water Levels



Local Water Levels



Gradient beneath and downslope of the tanks



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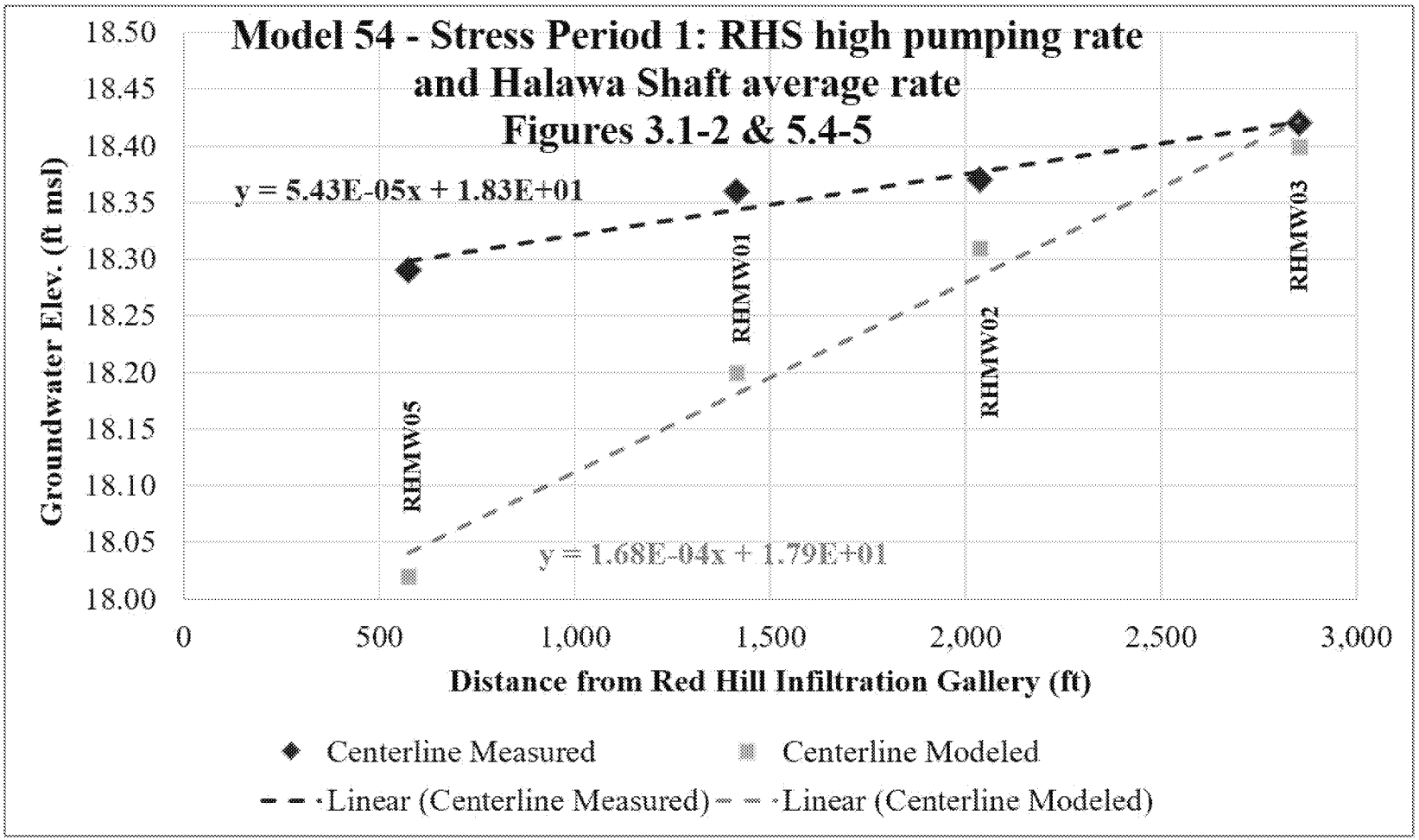
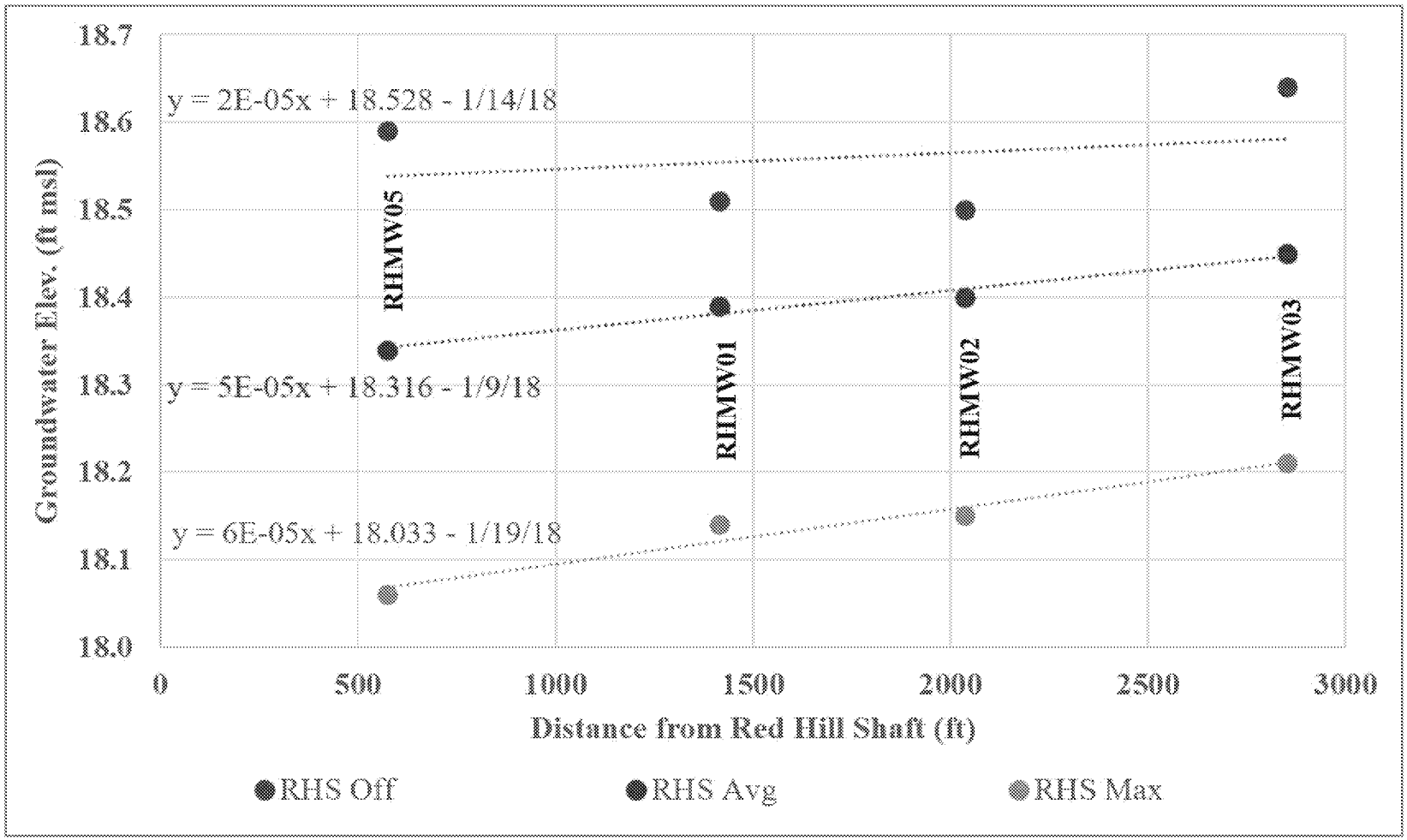


Red Hill Ridge gradient - under three different pumping conditions



Reliability of GW Elevation Data

magnitude and direction, which are a primary objective for the model. However, the measurements of absolute water levels or gradients between well pairs may incur errors due to datum measurements and borehole gyroscopic tape corrections for the reasons previously discussed. The spring fluxes at Pearl Harbor Spring at Kalauao and Kalauao Spring were also calibration targets with target values shown in Table 3-2. Weighting on these targets was determined after preliminary PEST simulations such that the flux magnitudes did not overwhelm water level targets in the objective function. Finally, the extraction rates at pumping wells were also included in the PEST multi-objective function to ensure that pumping did not reduce with bottom-hole conditions during calibration.

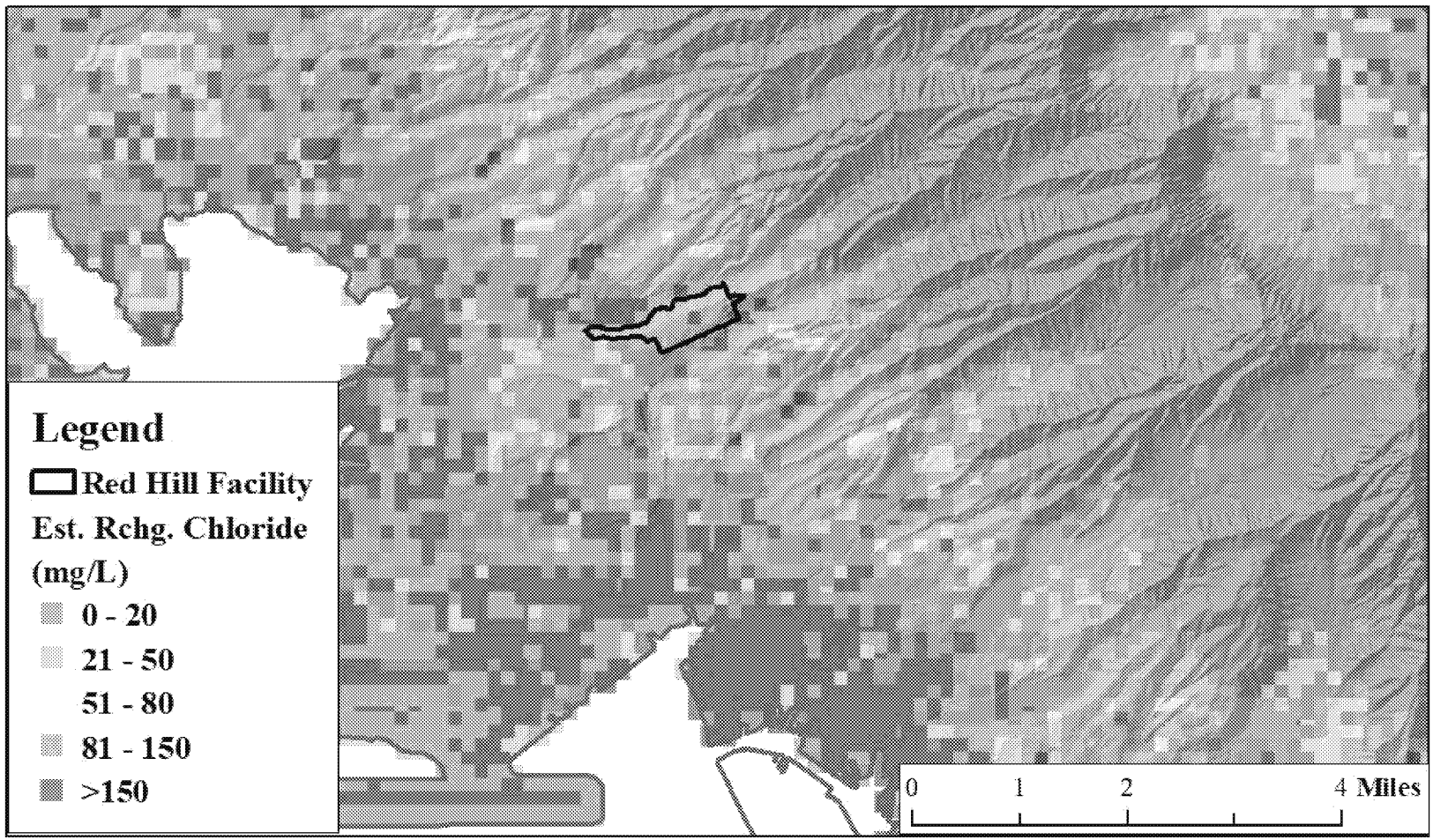
Additional Data – Natural tracers

9. Groundwater Data

Chemistry shows indication of a poorly mixed system

- Chloride conc. vary from ~40->1000 mg/L
- Southeast very different from northwest
- Northwest chlorides still highly variable
- A large flux of groundwater down the Red Hill ridge should show better mixing

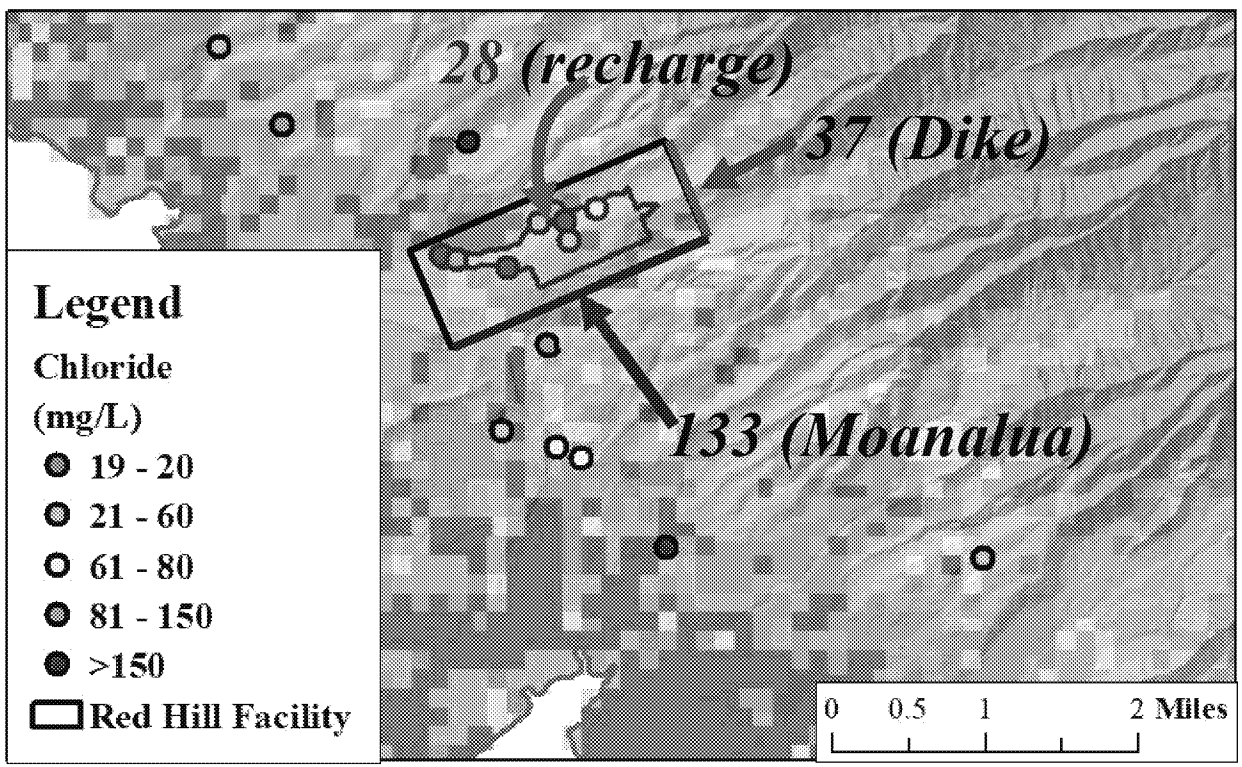
Estimated Chloride Conc. in Recharge

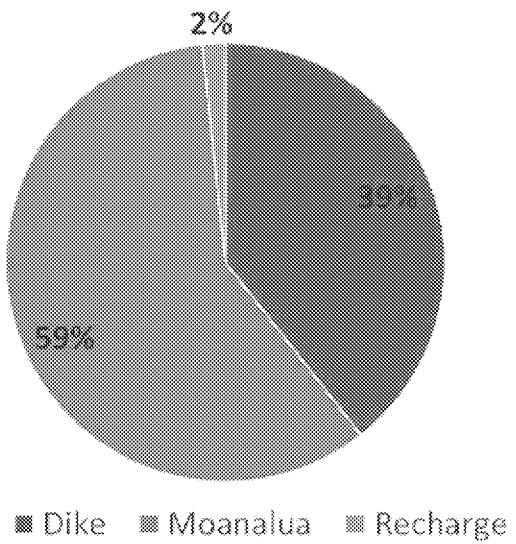


- Chloride in recharge estimated using the chloride mass balance approach
- Chloride concentration at the Facility <50 mg/L
  - Except for one pixel

Incorporating Geochemistry w/o Doing a Transport Model

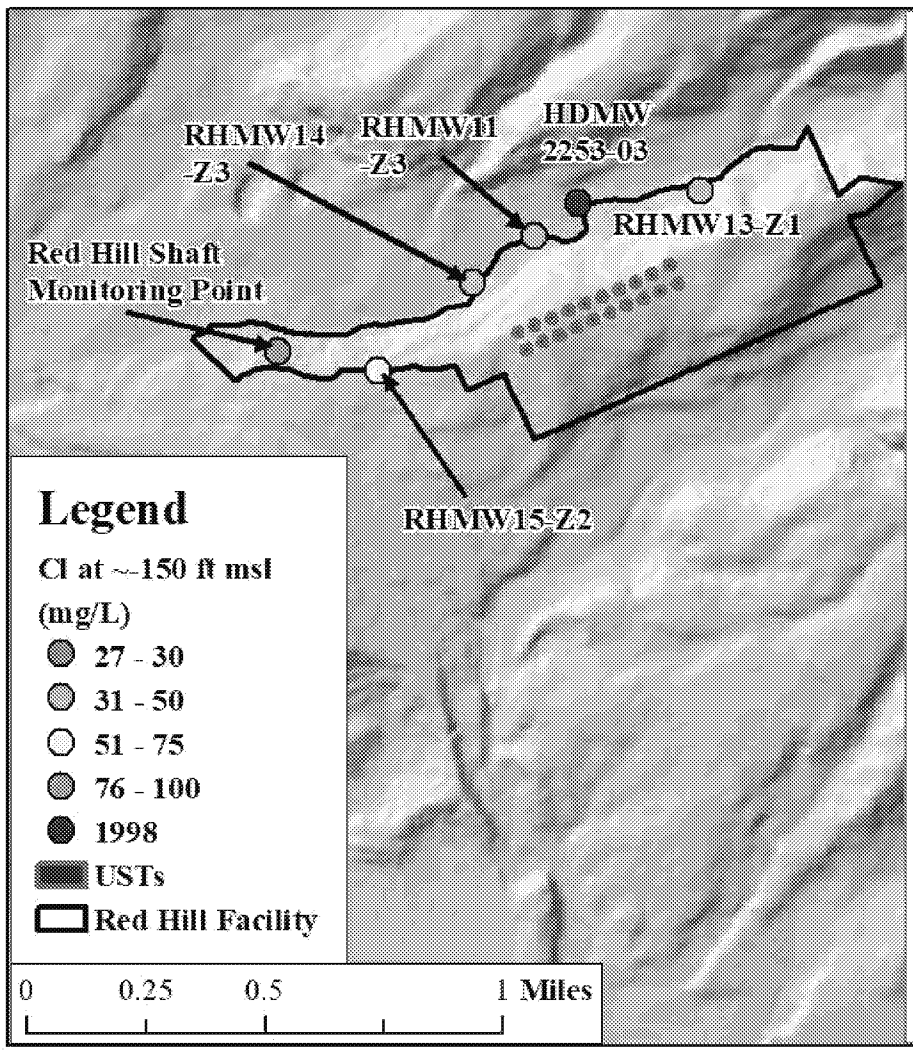
- Mixing Equation
  - $C_{mix}=(C_1*Q_1+C_2*Q_2+C_3*Q_3)/(Q_1+Q_2+Q_3)$
  - 93 mg/L = 2%*28 + 38%*37 + 59%*133
- Red Hill Shaft average chloride conc. ~ 95 mg/L
  - Chloride concentration is weighted Cl sum from the source areas

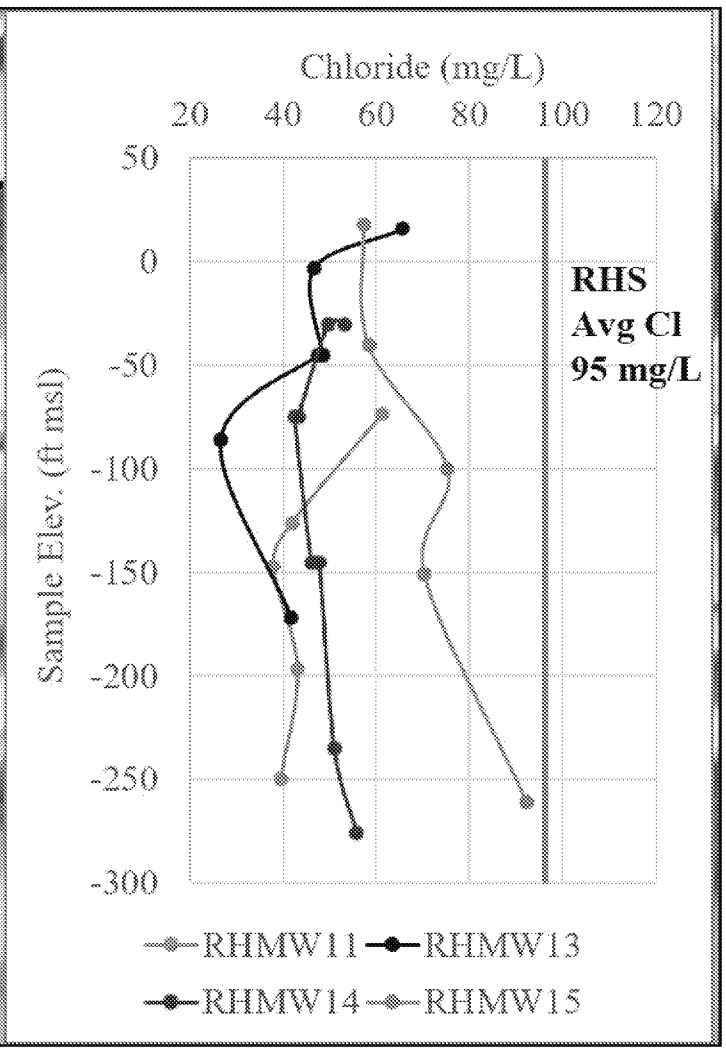




Numbers denote assumed chloride concentration

It is unlikely that chlorides originating in the Halawa region elevated the chloride concentration in the RHS





Application of model conclusions

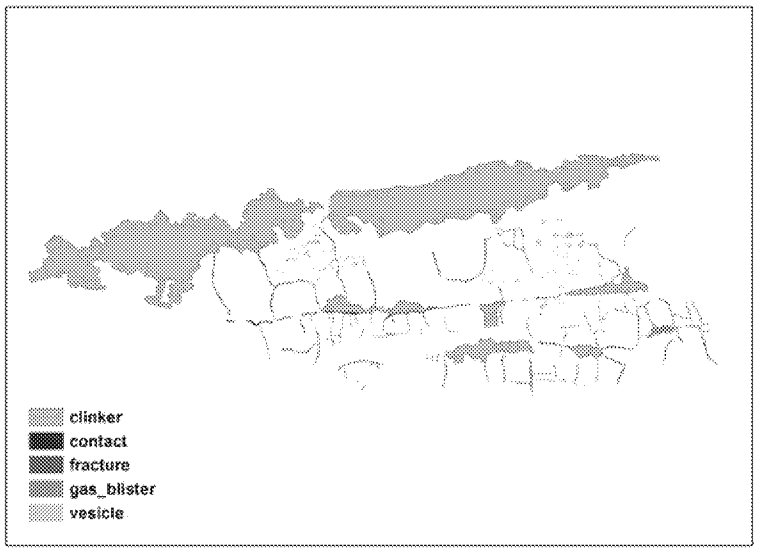
13 **2.3.2 Overview of Preliminary Capture Zone Analyses**

14 The GWFM Report (DON 2020b) is published concurrently with this IRR Report. The GWFM Report
15 describes the various models that are part of the multimodel approach, including capture zone analyses
16 that pertain to each model (including certain variations for specific models). The reverse and forward
17 particle track analyses presented in the report are related only to potential groundwater flow relative
18 to the assumptions in a particular model, and do not relate to potential contaminant flow; contaminant
19 flow will be determined as part of the CF&T modeling effort. Certain conclusions based on model
20 capture zones and associated particle tracks are provided below:

21 • All available capture zones indicate that when Red Hill Shaft is pumping at slightly below its
22 permitted rate of [redacted] million gallons per day [mgd]) and Hālawa Shaft is pumping at slightly
23 above its permitted rate of 11.320 mgd, the Red Hill Shaft capture zone extends across the
24 entire tank farm. As such, potential releases from any tank would be contained in the Red Hill
25 Shaft capture zone.

- Investigation and Remediation of Releases Report; Page 2-18
- Issues previously discussed cast doubt on the assumption the Red Hill Shaft will contain the offsite migration of any contaminant plume
- The model results are currently not informative for developing release response plans
  - Questions regarding the ability of the RHS to capture a contaminant plume and the risk the Halawa Shaft remain unanswered

Further GWFM & CSM Review Items



DOH Technical Team:

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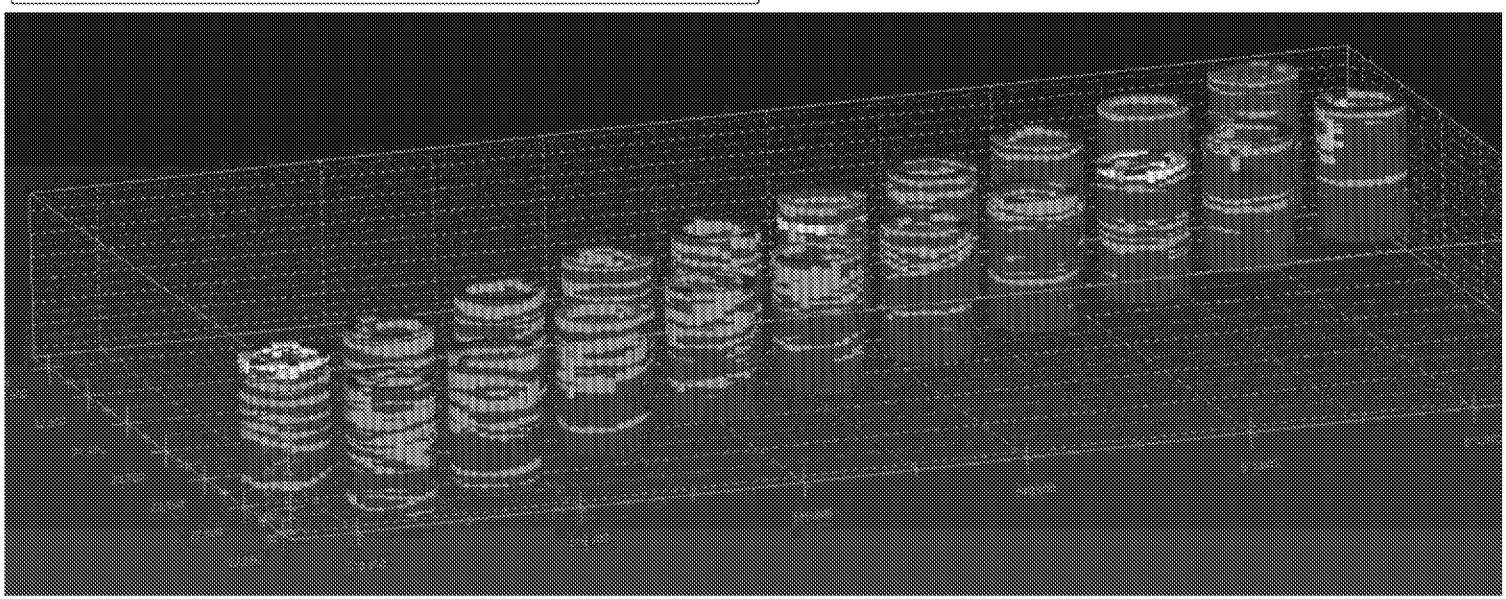
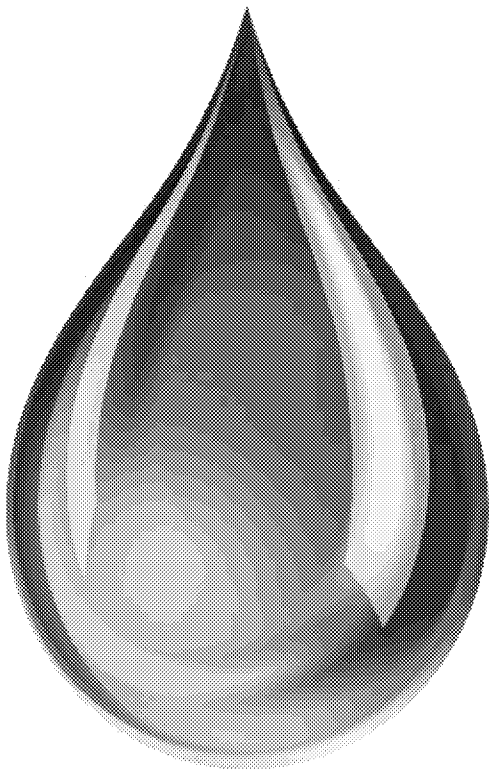
G.D. Beckett, C.Hg.
Anay Shende, DOH
Dr. Matt Tonkin, EPA (review)

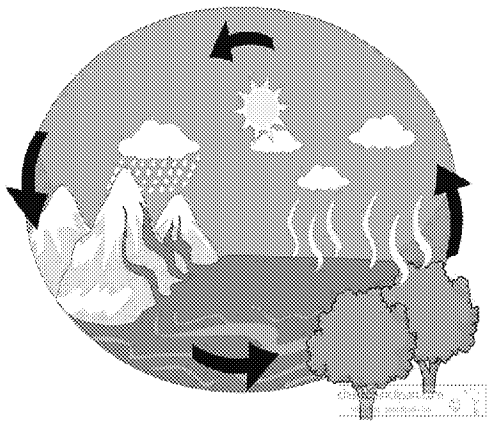


Key Groundwater Model Objective



- The purpose of this deliverable is to refine the existing groundwater flow model and improve the understanding of the direction and rate of groundwater flow within the aquifers around the Facility (AOC, 2015)
  - *To do this, the underlying hydrogeologic conditions must be refined and better understood in light of new data not available to prior modeling*

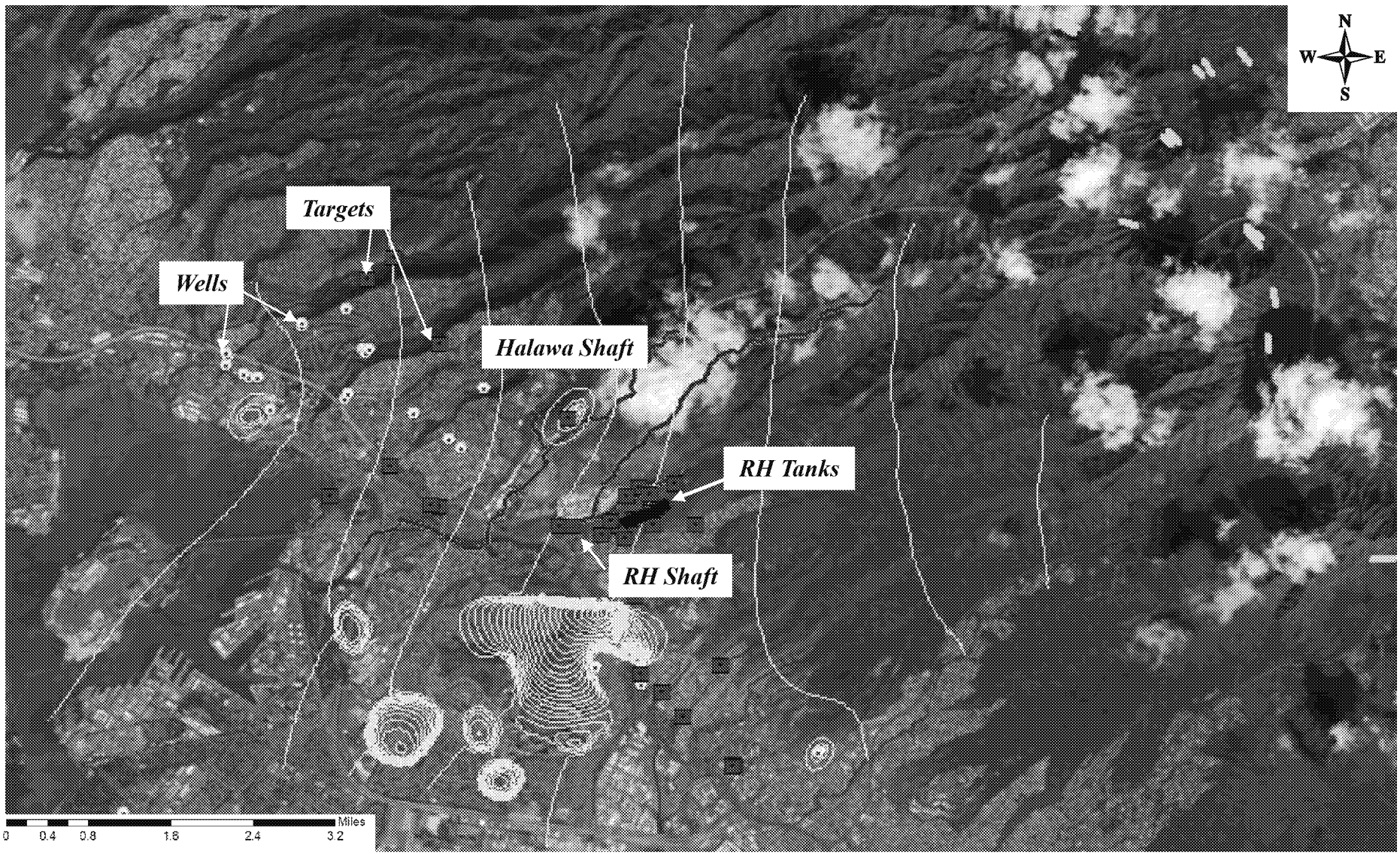
The Navy Has Delivered Multiple Models



- Key review questions:
  - Do the models represent local heads?
  - Gradients?
  - Transient aspects?
    - Pumping from Red Hill & Halawa shafts
    - Monitoring well response "groupings"
  - Do transient simulations better past models?
  - Are models consistent with geochemistry?
    - And with dissolved-phase patterns?
  - Are models parameters appropriate?
- Will the model(s) inform risk estimates?
  - Most uncertain aspect is NAPL
    - Where is it presently & in what state?
    - How far/fast could releases travel?
  - What are the key processes?
  - Are those adequately described & demonstrated?

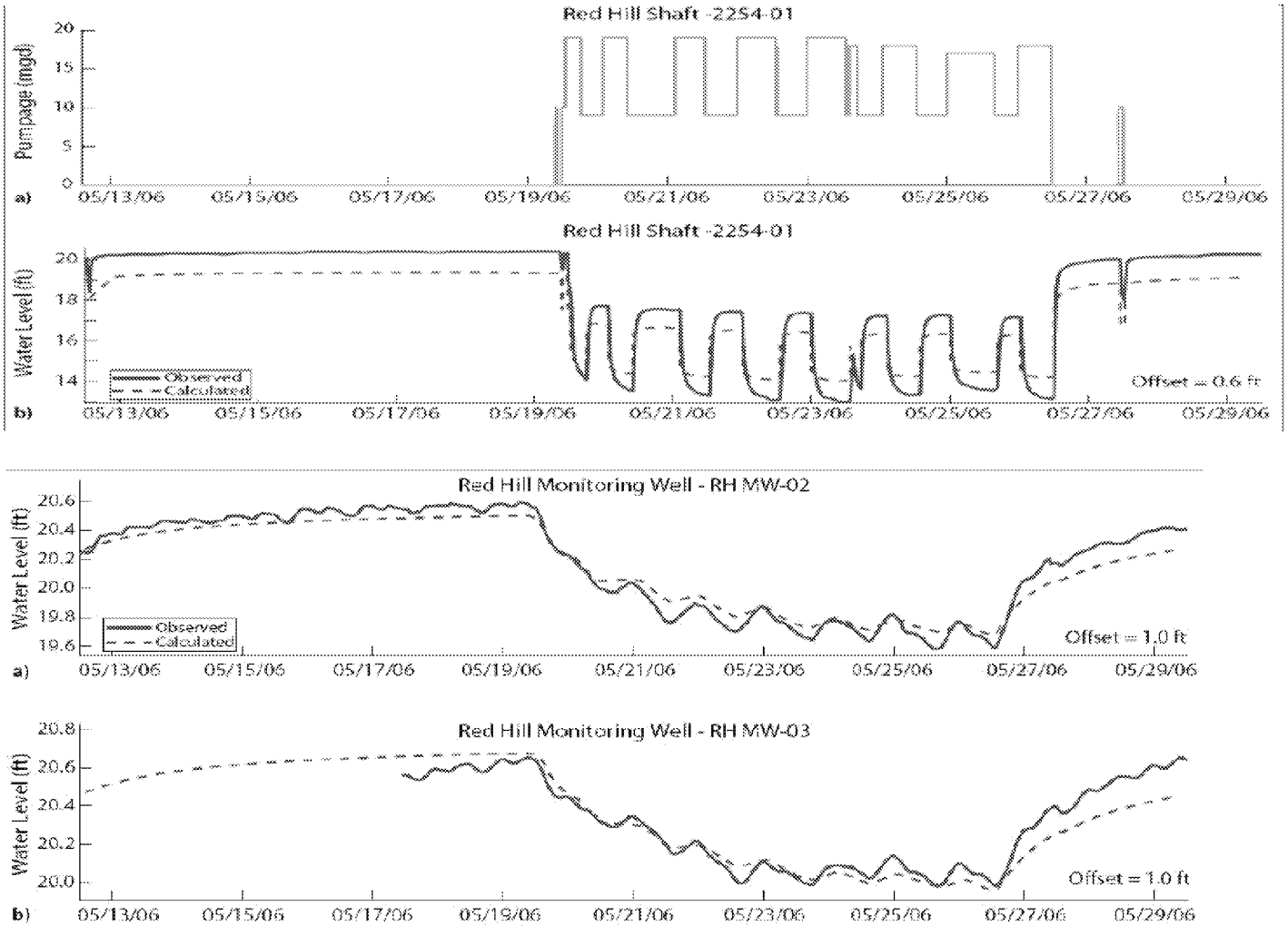
General Area/Model Map

(Halawa Shaft On, RH Shaft Off)



The Primary Issue with Prior Model

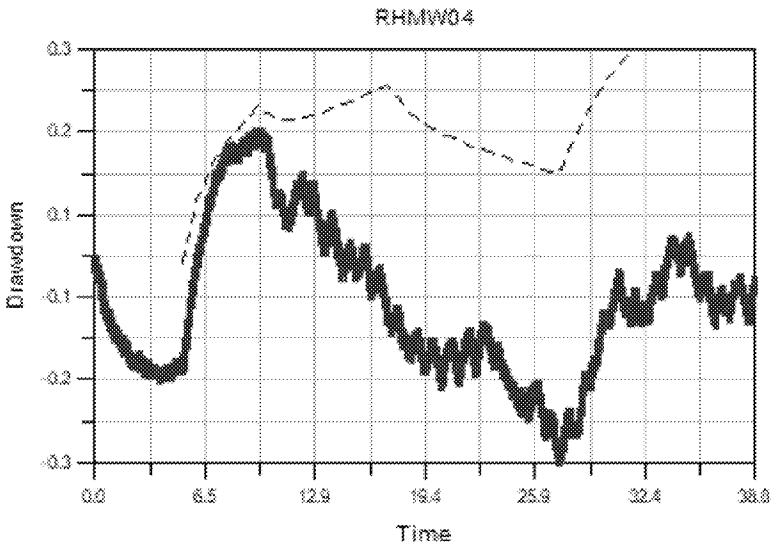
(calibrated to drawdown, but not to heads; complexity)

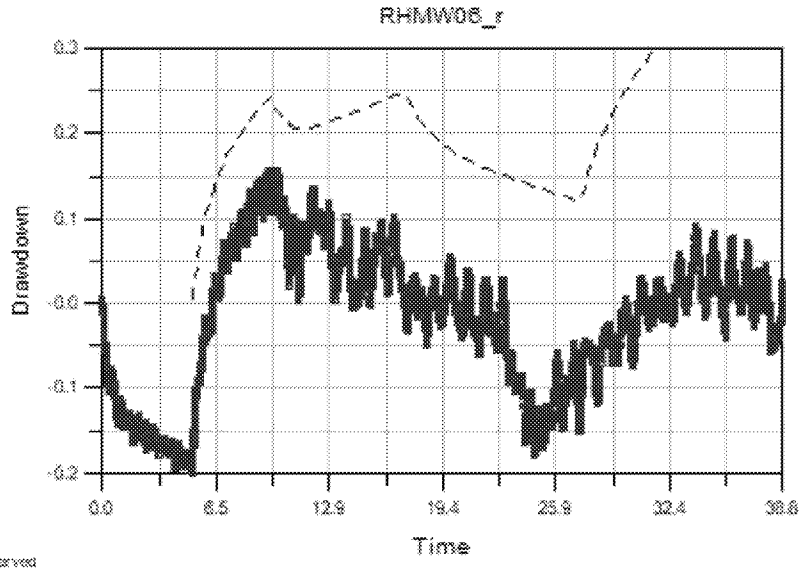


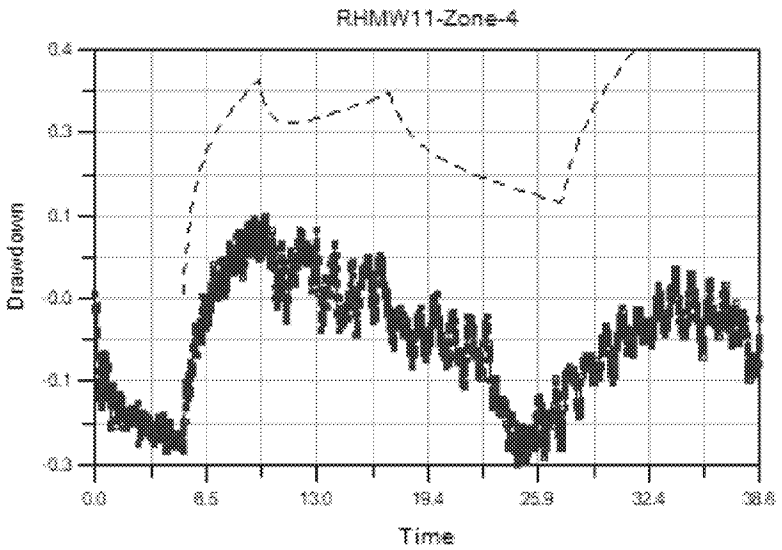
Kolja Rotzoll and Aly I. El-Kadi, 2007

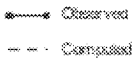
Example Hydrographs; M51a Verification

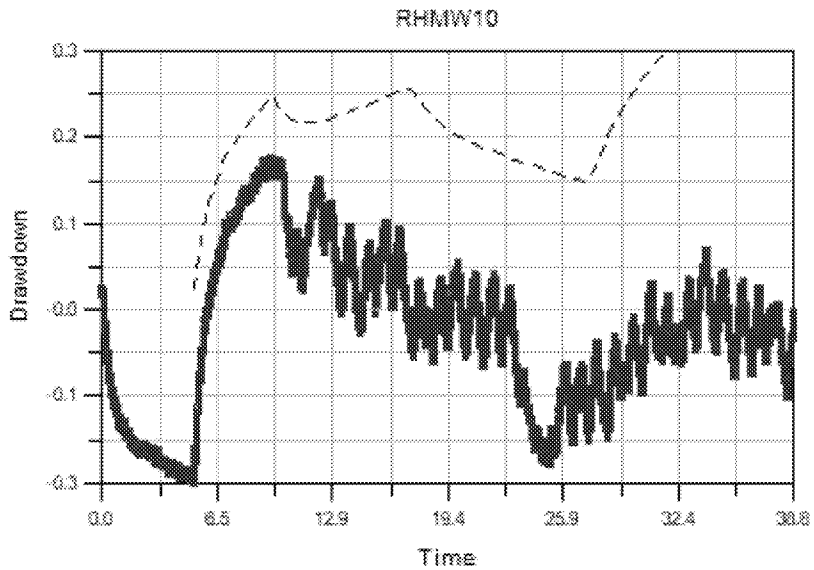
(charts are direct model output – GWV)



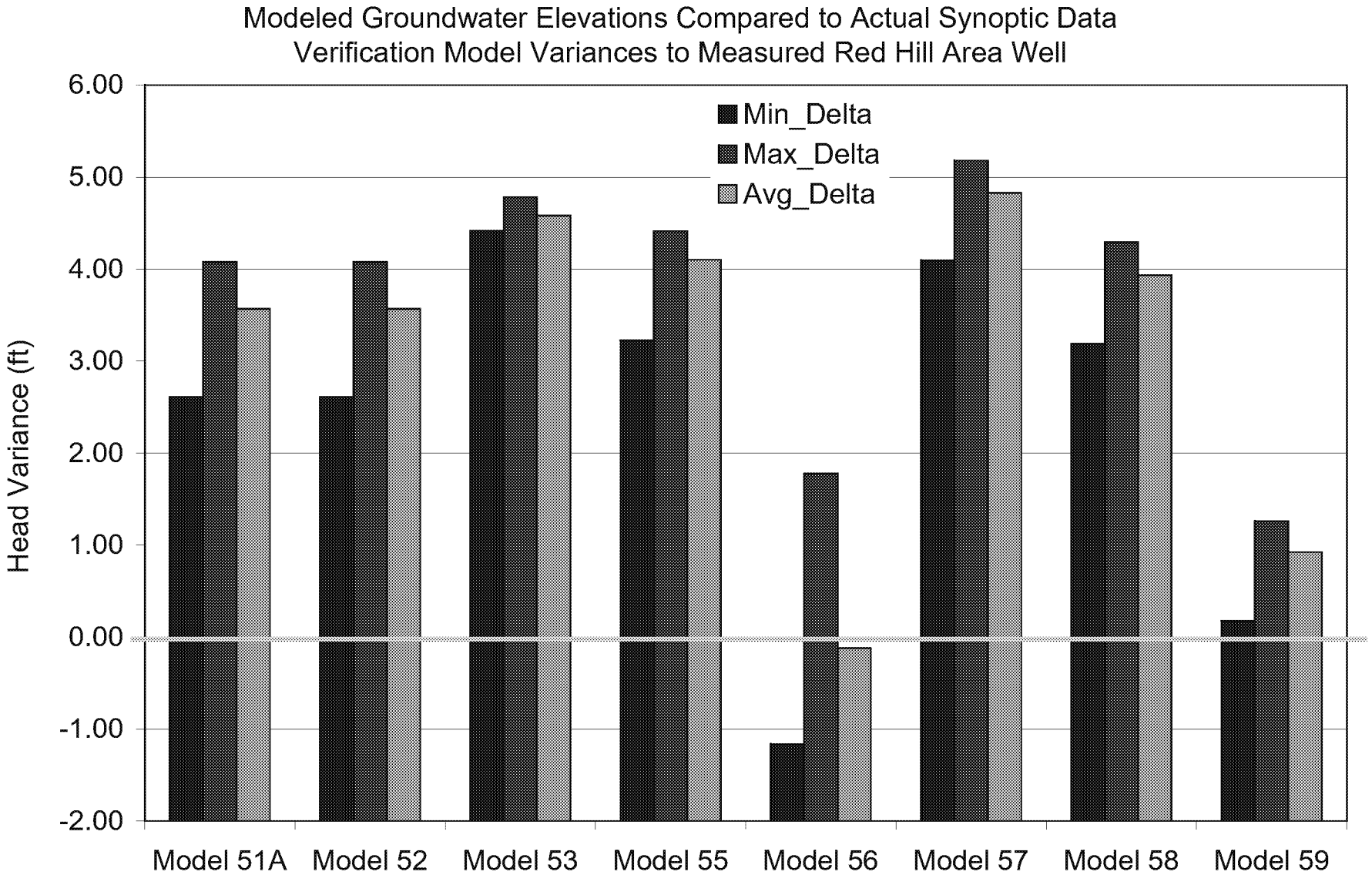




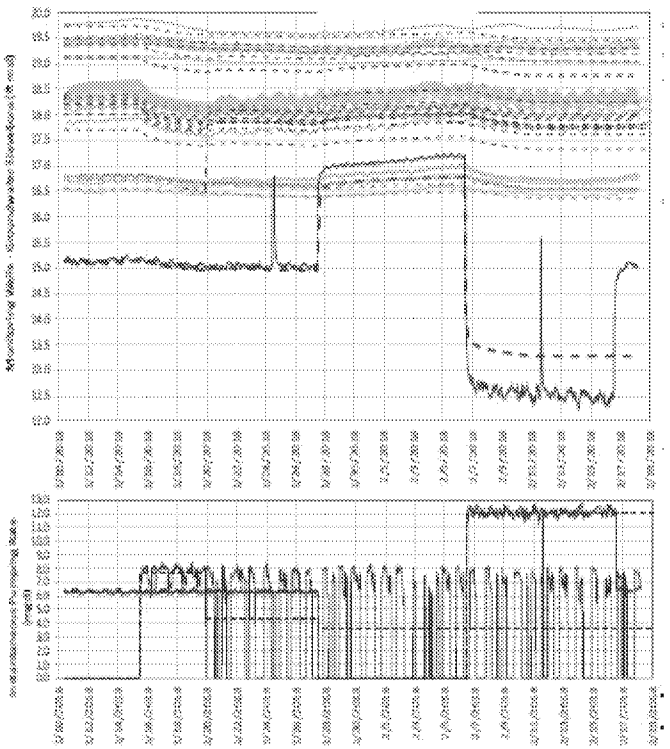




GW Elevation Variance – Transient Models



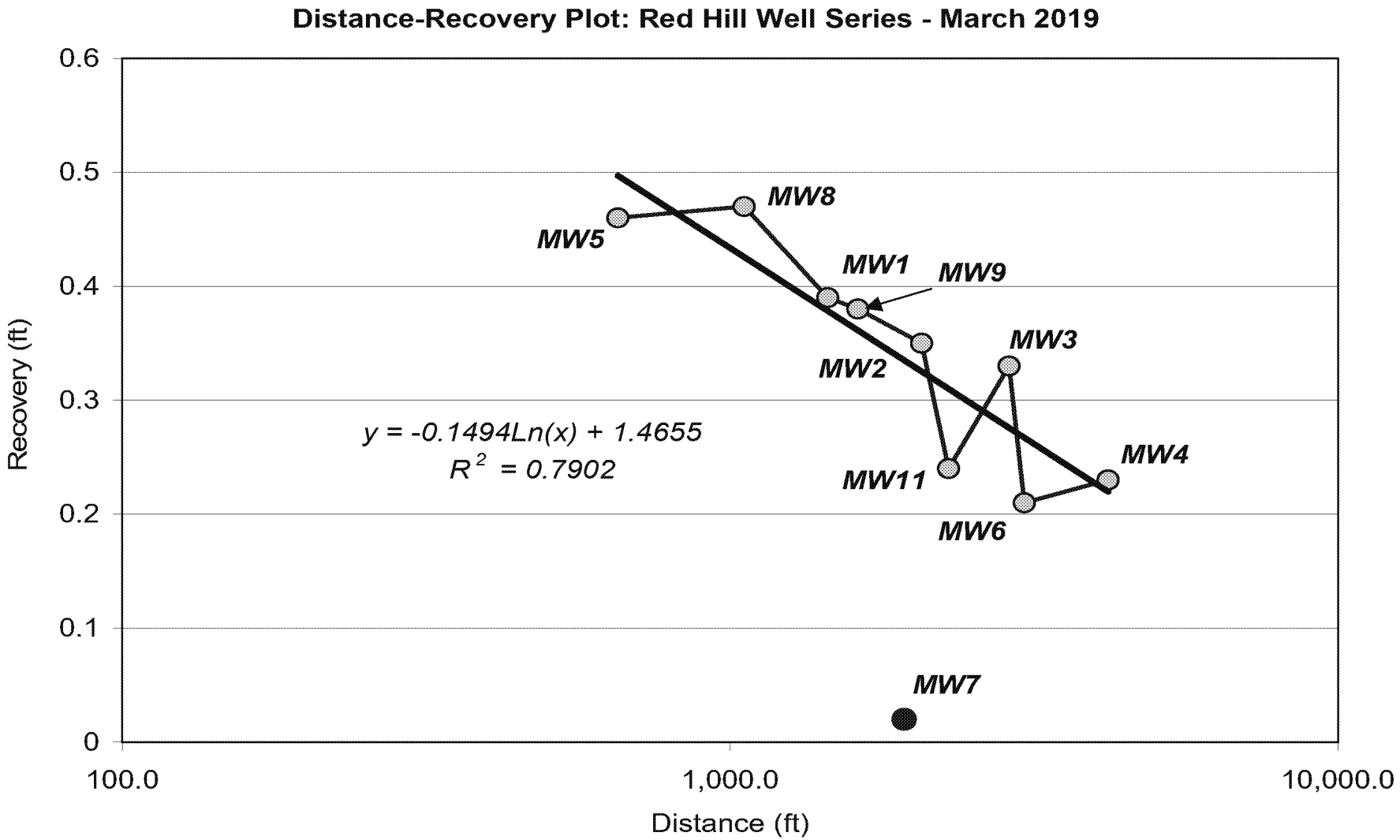
Objectives of Verification Models



- Verification means just that
  - A "blind" test of the GWFMs predictions
  - How well do they agree with data
    - In this case, water level elevations
- How is this typically implemented?
  - Calibrate main models
  - Run them in transient mode against site data
    - From different period of time
  - See how well each model reflects the data
- Purpose
  - Identify deficiencies in main models
  - Identify which are "best fits"
  - Consider transient implications
  - Consider compartmental responses (& others)
- Issue, we cannot replicate the reported results
  - Plots do not agree with model output
  - Appears to be a superposition
    - Model drawdown upon measured elevation data
- This was the same issue in prior models
  - Recall primary AOC objective

Non-Uniform Distance Drawdown Behavior

(indicates complexities not captured by models)

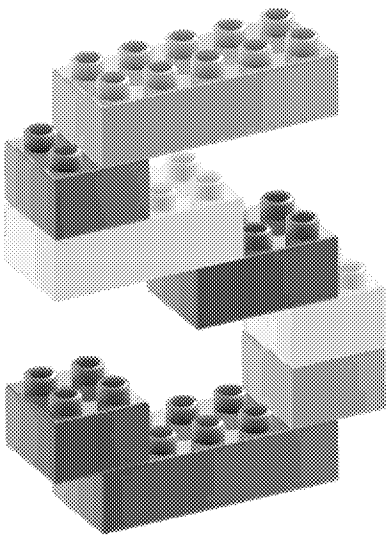


Prior Key Parameters v. Navy Models

(ranges are inconsistent & w/o explanations)

	Oki, 2005			Navy GWFM - avgs		
Hydrostratigraphic Unit	Kv	Kt	Kl	Kv	Kt	Kl
Volcanic-rock aquifer	7.5	1,500	4,500	65	1,000	2,999
Caprock, upper-limestone unit	25	2,500	2,500	0.01	500	500
Caprock, low-permeability unit						
Above Waianae Volcanics	0.3	0.3	0.3	0.01	1	1
Above Koolau Basalt, west of Waiawa Stream	0.01	0.01	0.01	0.01	1	1
Above Koolau Basalt, east of Waiawa Stream	0.6	0.6	0.6	0.01	1	1
Valley-fill barriers	0.058	0.058	0.058	0.01	1	1

Key Model Review Observations



- GWFMs do not match heads, diminishing reliability
  - In transient verification runs
  - Similar issue as in prior modeling (2007)
- GWFMs use atypical parameters for Hawaii aquifer
  - If retained, in depth justification needed
- GWFMs do not use CSM geologic details – SSPA work
  - Impact of heterogeneity needs detailed evaluation
- GWFMs do not comport with natural g.w. tracers
  - Complex distributions may imply multiple source waters
- GWFMs capture zones not supported by field data at pumping rates similar to those modeled
  - Parameters used may overestimate capture potential
  - Gradient issues & complexity not covered
- As the GWFM's currently stand, they are not reliable
  - For CF&T, risk analyses and mitigation decisions
- Modifications will be needed (SSPA work follows)

Ongoing Issues with the Navy CSM

The CSM being the fundamental basis for the Navy GWFMs, future CF&T/Risk Evaluations and the overall key conditions at the Red Hill Bulk Fuel Storage Facility

The CSM is not an AOC deliverable

The Hawaii Hard Rock Release Experience

Source: Don Thomas, 2021

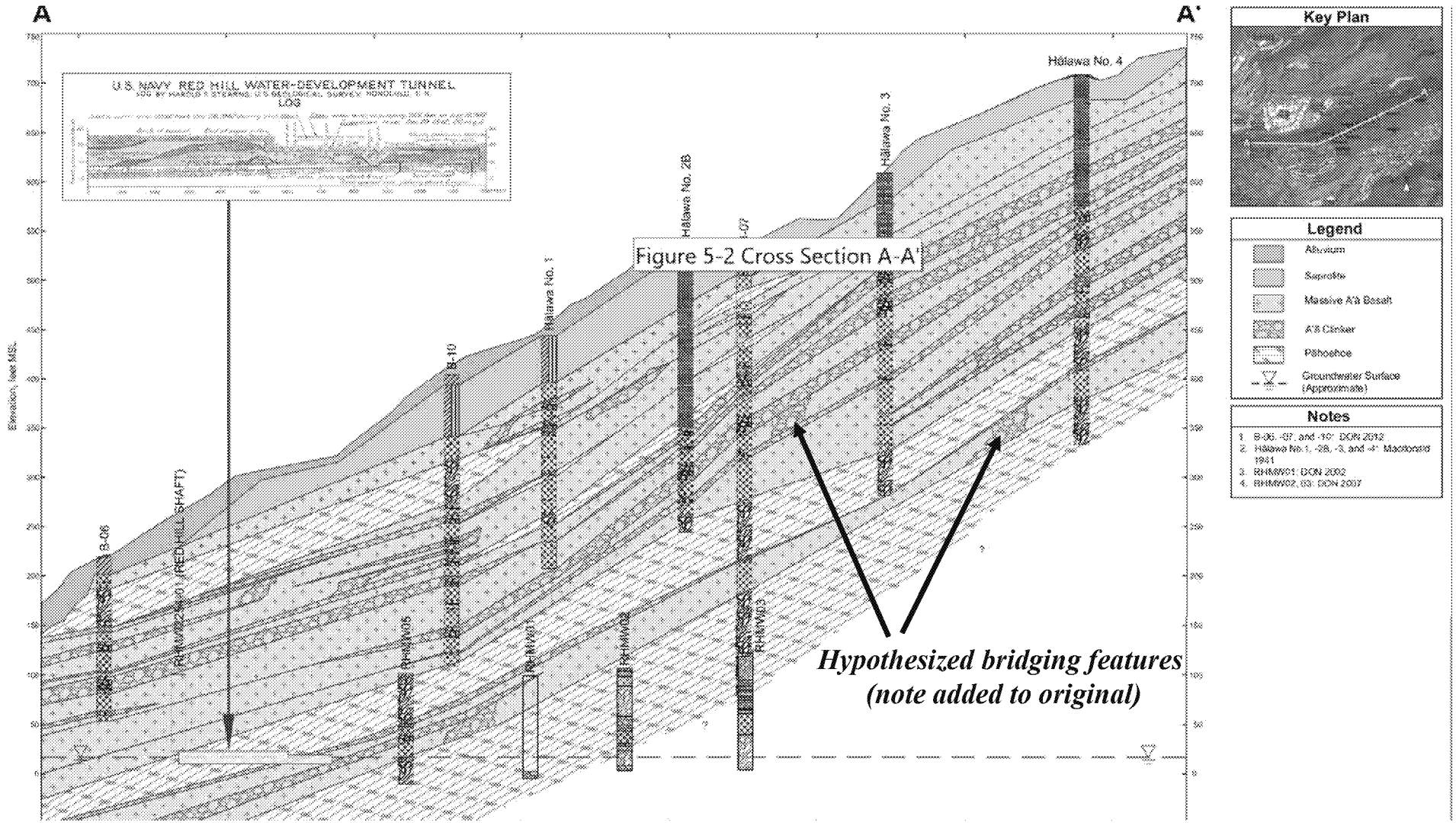
- Fuel releases often move quickly
  - Typically in complex pathways
    - Primary & secondary transport
  - Often difficult to characterize
- Fast-track/other geologic features exist
  - Lava tubes, voids, fractures, clinkers
  - Confining beds & non-volcanics
  - Preferred & random orientation scales
  - Often sparse distribution, large effect
- Weathering of rock is complex
  - Bulk rock properties may not apply
- For Red Hill
  - How is the architecture arranged?
  - How will fuel behave within that?
  - Effects on capture/remediation?
  - All relates to g.w. protection goals
    - And sole source aquifer preservation

Overview – Unresolved CSM Issues

Source: Dr. Scott Rowland, 2021

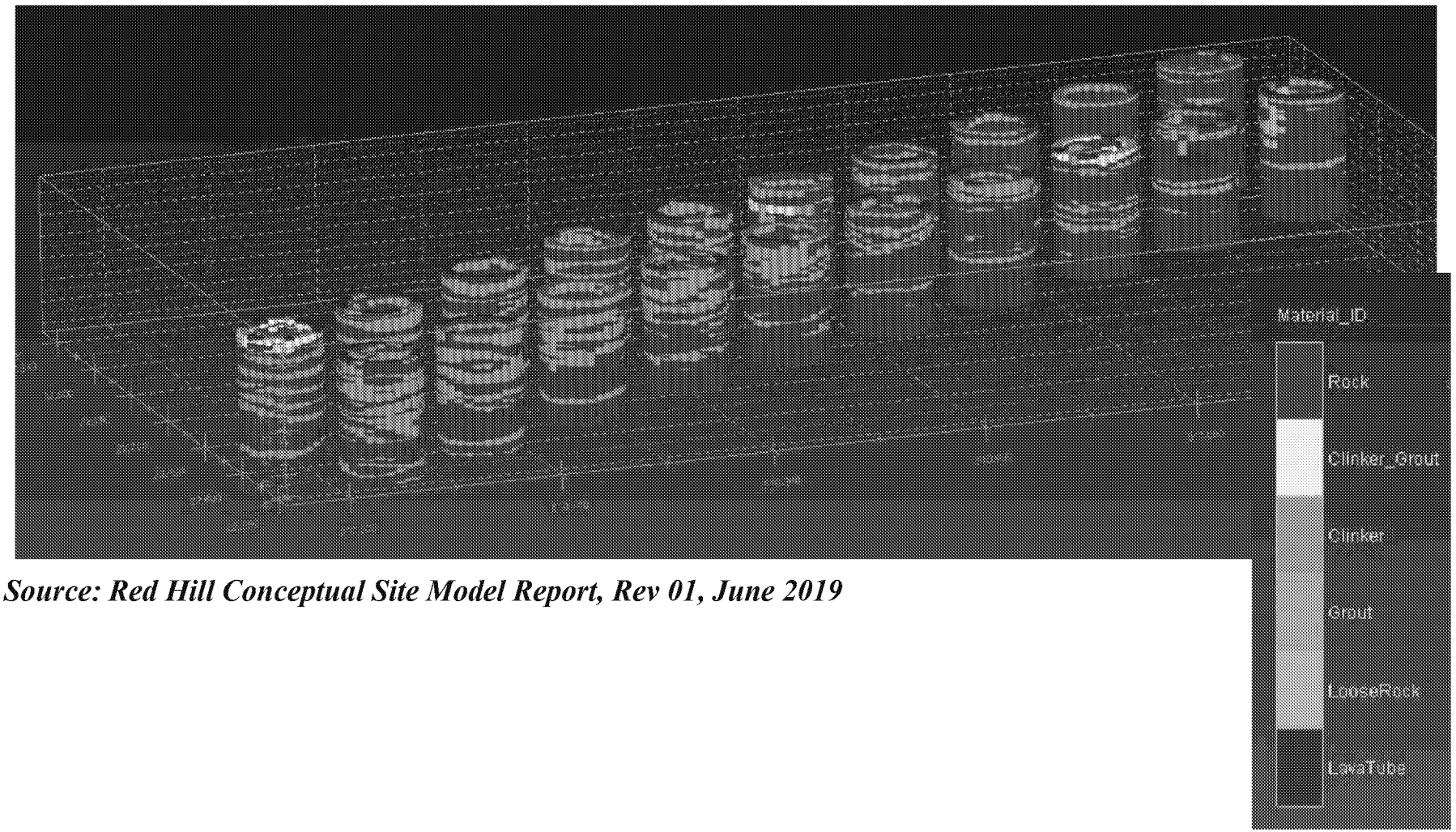
- Red Hill is spatially under-characterized
  - Compared to similar sites
  - Results in high uncertainty in the CSM
- Complex geology is noted in CSM
  - But, simplified in GWFMs
  - No basis for appropriate CF&T
  - G.W. & CF&T behavior appears more complex
- Data indicate TPH beyond RH Ridge
  - CSM interprets these as artifacts (generally)
- CSM indicates LNAPL migration to SW
  - But available data indicate otherwise
- CSM indicates fuel retained ~ 30-ft depth
  - Not supported by available data
- Fuel retention characteristics are unknown
  - Fuel/NAPL parameters inapplicable
  - Geometry unconstrained by data
  - Dynamics are critical to g.w. protection
- Many other issues remain
- In total, CSM is not reliable for g.w. protection

Example Navy CSM Cross-Section



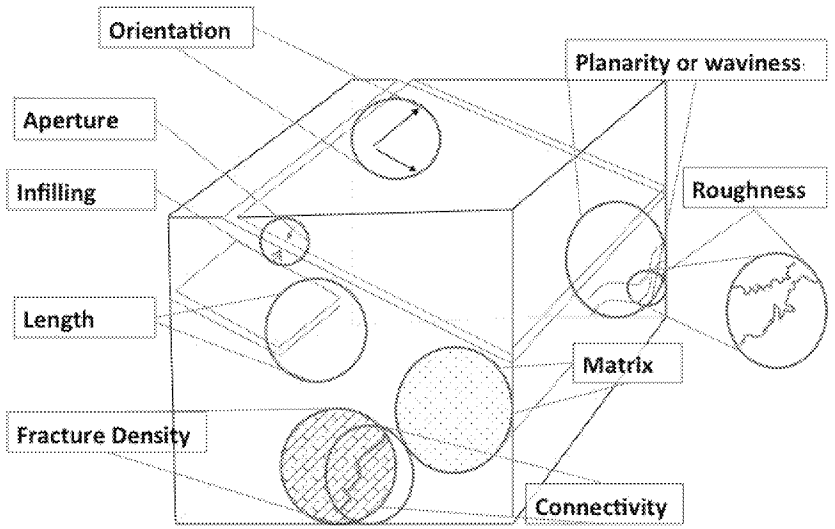
Source: Red Hill Conceptual Site Model Report, Rev 01, June 2019

Navy 3D Lithologic Model – Barrel Logs
(Dr. Tonkin will show a way to consider heterogeneity)



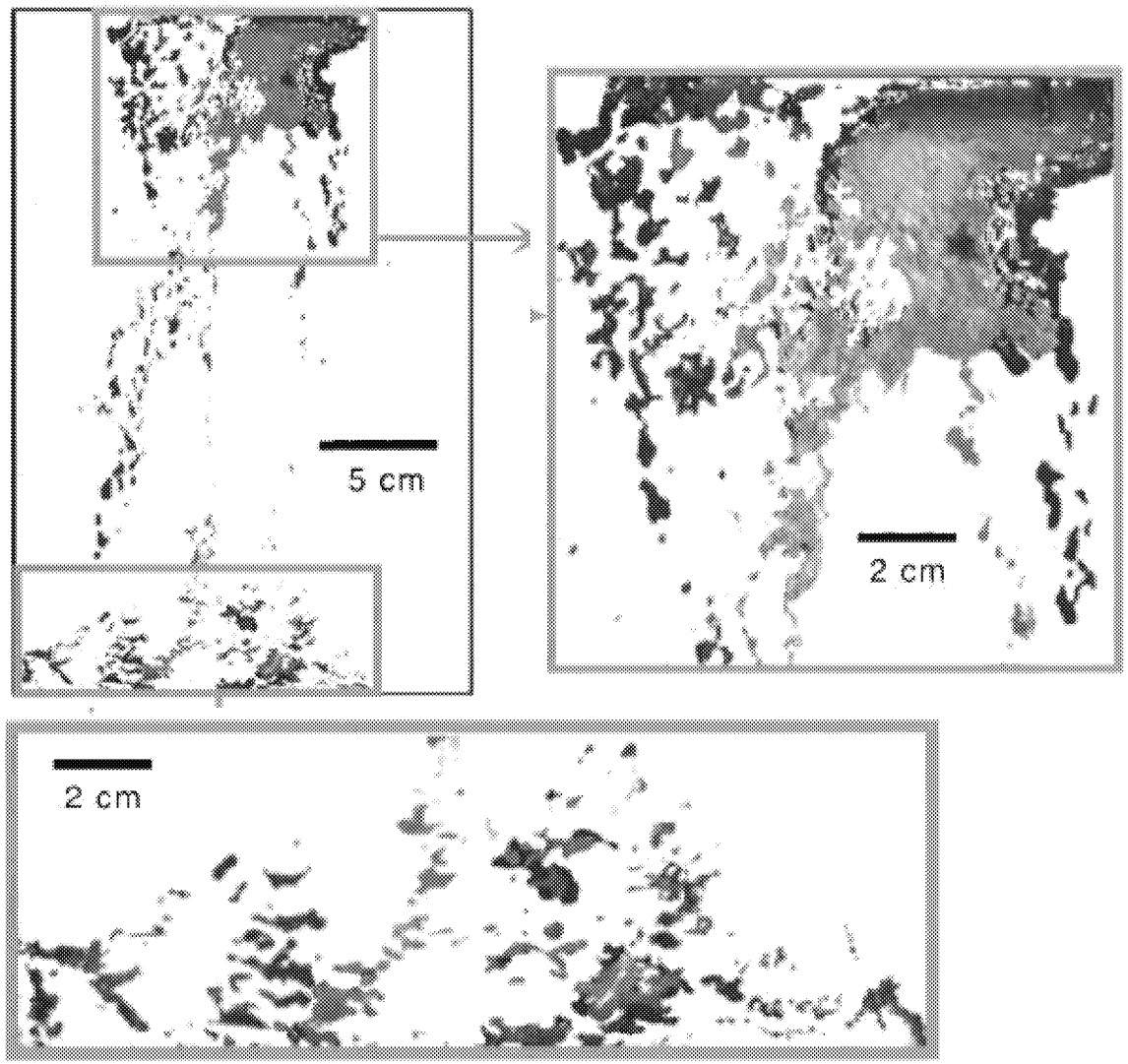
Source: Red Hill Conceptual Site Model Report, Rev 01, June 2019

Outcrop Interpretation – Dr. Scott Rowland (UH)



Source: ITRC, 2017

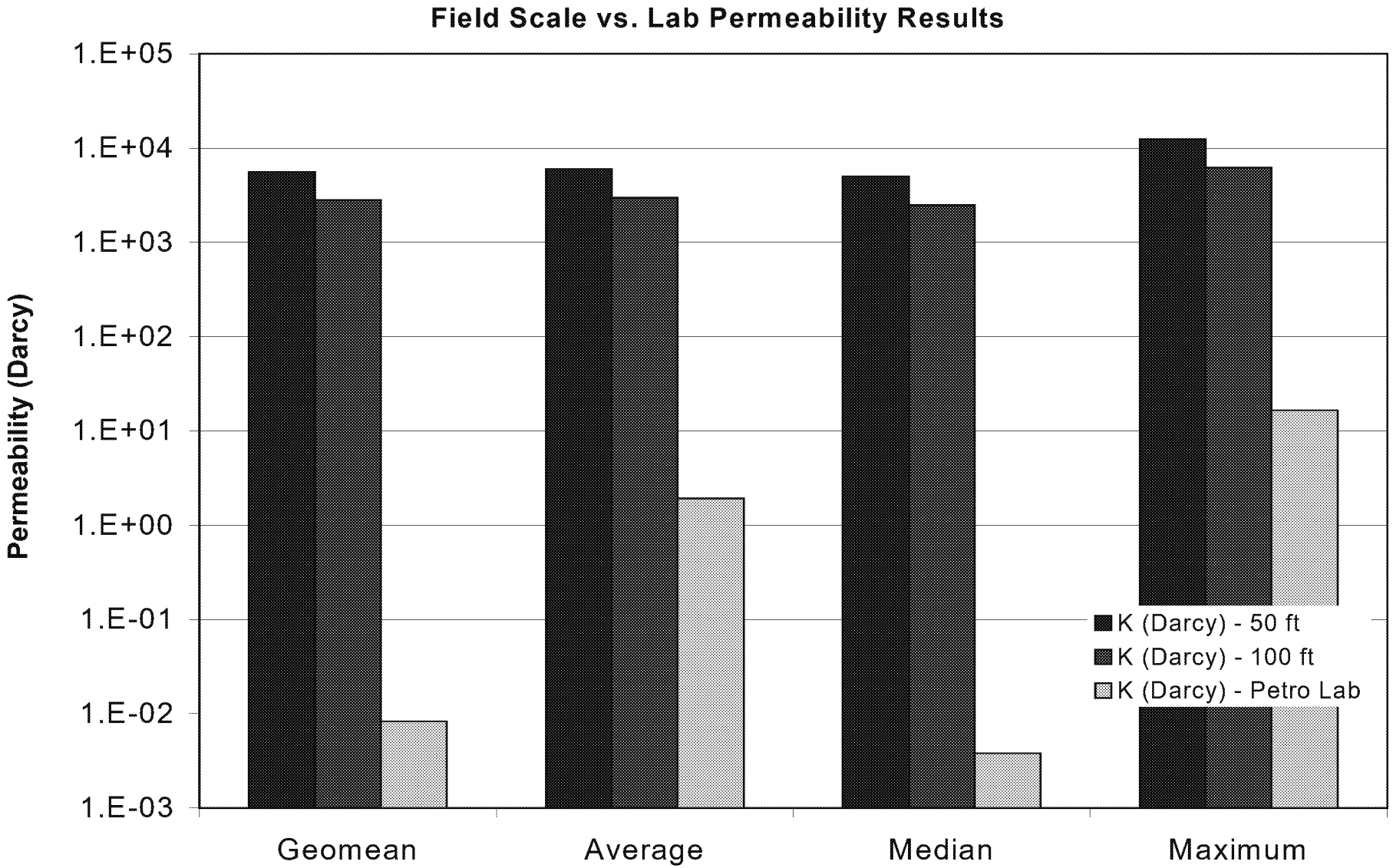
Complex NAPL Distribution in a Fracture



Geller et al., 2000

Lab vs. Field Scale – Permeability

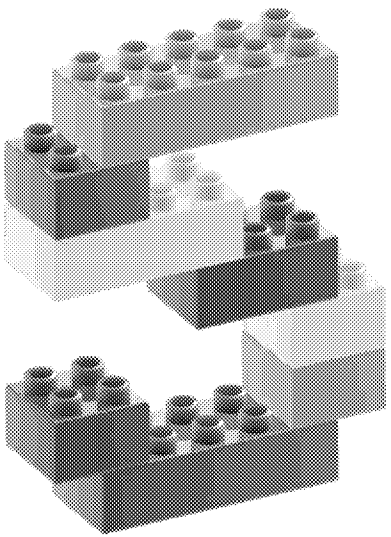
(Site lab data vastly under-represent field scale permeability)



Data source: Conceptual Site Model, June 2019, Rev 01

Summary & Implications of CSM Issues

(broad issues, many other details pertain)



- The complexity of the site is not well characterized
  - Nor are the fuel impacts below and around Red Hill
- NSZD is likely overestimated & uncertain
  - Impacts at RHMW03 (> 20 yrs); RHMW01R no LNAPL
- G.W. capture of releases is not demonstrated
  - By field data or adequately by GWFMs
- G.W. protection actions depend on several factors
  - How fuel migrates under release conditions
  - Speed and effectiveness of release detection & actions
- Capture may not be an appropriate G.W. remedy
  - Nexus between fuel migration rates & remedy must be considered
  - Capture is not a cleanup method – relies on uncertain NSZD
  - However, g.w. treatment may protect water services
- Red Hill Shaft is indicated to be at risk from releases
  - Proximity & history of low-level detections (including July 2021)
  - Dilution & NSZD make this both surprising & concerning
- Risk evaluations must be connected to a conservative CSM
  - Presently, there is insufficient conservatism in the CSM
  - Along with high uncertainty that is not addressed